

## Category-IV

### COMMON POOL OF GENERIC ELECTIVES (GE) COURSES OFFERED BY THE DEPARTMENTS

| Course Title & Code                      | Credits | Credit distribution<br>of the course |          |           | Eligibility<br>criteria | Pre-requisite<br>of the course |
|------------------------------------------|---------|--------------------------------------|----------|-----------|-------------------------|--------------------------------|
|                                          |         | Lecture                              | Tutorial | Practical |                         |                                |
| Electricity and Magnetism<br><br>GE – 11 | 4       | 3                                    | 0        | 1         | Class XII pass          | NIL                            |

#### **LEARNING OBJECTIVES**

This course begins with theorems of network analysis which are required to perform the associated experiments in the laboratory. Then course delves into the elementary vector analysis, an essential mathematical tool for understanding static electric field and magnetic field. By the end of the course, the student should appreciate Maxwell's equations.

#### **LEARNING OUTCOMES**

At the end of this course the student will be able to,

- Apply Coulomb's law to line, surface, and volume distributions of charges.
- Apply Gauss's law of electrostatics to distribution of charges
- Understand the effects of electric polarization and concepts of bound charges in dielectric materials
- Understand and calculate the vector potential and magnetic field of arbitrary current distribution
- Understand the concept of bound currents and ferromagnetism in magnetic materials

#### **SYLLABUS OF GE – 11**

#### **THEORY COMPONENT**

##### **Unit 1: (15 Hours)**

Network Analysis: Superposition, Thevenin, Norton theorems and their applications in DC and AC circuits with more than one source, Maximum Power Transfer theorem for AC circuits  
Mathematical Preliminaries: Concept of scalar and vector fields, Gradient of a scalar field, Divergence and curl of vector fields and their physical interpretation, Conservative forces and Laplace and Poisson equations.

Concept of a line integral of a scalar and vector field, surface integral of vector fields and volume integral, Gauss's theorem, Stoke's theorem.

**Unit 2: (15 Hours)**

Electric Field and Electric Potential for continuous charge distributions: Electric field due to a line charge, surface charge and volume charge distributions, Electric field vector as negative gradient of scalar potential, Ambiguities of Electric potential, Differential and integral forms of Gauss's Law, Applications of Gauss's Law to various charge distributions with spherical, cylindrical and planar symmetries, Uniqueness theorem

Electric Field in Matter: Bound charges due to polarization and their physical interpretation. Average electric field inside a dielectric, Electric Field in spherical and cylindrical cavities of a dielectric, Displacement vector and its boundary conditions, Gauss' Law in the presence of dielectrics, Linear dielectrics: electric susceptibility and dielectric constant, Boundary value problems with linear dielectrics.

**Unit 3: (15 Hours)**

Magnetic Field: Divergence and curl of magnetic field B, Magnetic field due to arbitrary current distribution using Biot-Savart law, Ampere's law, integral and differential forms of Ampere's Law, Vector potential and its ambiguities.

Magnetic Properties of Matter: Magnetization vector, Bound Currents, Magnetic Intensity, Differential and integral form of Ampere's Law in the presence of magnetised materials, Magnetic susceptibility and permeability, Ferromagnetism (Hund's rule)

Electrodynamics: Faraday's Law, Lenz's Law, inductance, Electromotive force, Ohm's Law ( $\vec{J} = \sigma \vec{E}$ ), Energy stored in a Magnetic Field. Charge Conservation, Continuity equation, Differential and integral forms of Maxwell's equations in matter.

**References:****Essential Readings:**

- 1) Introduction to Electrodynamics, D. J. Griffiths, 4th Edn., 2015, Pearson Education India Learning Private Limited.
- 2) Schaum's Outlines of Electromagnetics, M. Nahvi and J. A. Edminister, 2019, McGraw-Hill Education.
- 3) Electromagnetic Fields and Waves, Paul Lorrain and Dale Corson, 1991, W. H. Freeman.
- 4) Electricity and Magnetism, Edward M. Purcell, 1986, McGraw-Hill Education
- 5) Network, Lines and Fields, John D. Ryder, 2nd Edn., 2015, Pearson.
- 6) Introductory Circuit Analysis, R. Boylestead, 2016, Pearson.
- 7) Electricity and Magnetism, Tom Weideman, University of California Davis.  
[url: [https://zhu.physics.ucdavis.edu/Physics9C-C\\_2021/Physics%20C\\_EM%20by%20Tom%20Weideman.pdf](https://zhu.physics.ucdavis.edu/Physics9C-C_2021/Physics%20C_EM%20by%20Tom%20Weideman.pdf)]

**Additional Readings:**

- 1) Feynman Lectures Vol. 2, R. P. Feynman, R. B. Leighton, M. Sands, 2008, Pearson Education
- 2) Electricity, Magnetism and Electromagnetic Theory, S. Mahajan and Choudhury, 2012, Tata McGraw
- 3) Fundamentals of Physics, Resnick, Halliday and Walker 10/e, 2013, Wiley

**PRACTICAL COMPONENT- 30 Hours**

Learning Outcome:

- To understand working of Arduino Microcontroller System
- To use Arduino to measure time, count events and time between events
- To use Arduino to measure voltage/current/resistance
- To use Arduino to measure various physical parameters like magnetic field

#### **Unit I (Mandatory): Arduino Programming**

Introduction to Arduino Microcontroller platform. Getting acquainted with the Arduino IDE and Basic Sketch structure. Digital Input and output. Measuring time and events. Measuring analog voltage. Generating analog voltage using Pulse Width Modulation. Serial communication and serial monitor. Programming using Interrupts.

#### **Unit II: Exploring electrical properties of matter using Arduino** (at least one experiment)

- To study the characteristics of a series RC Circuit.
- To study response curve of a Series LCR circuit and determine its (a) Resonant frequency, Impedance at resonance, (c) Quality factor Q, and (d) Band width.
- Diode Characteristics:
  - To study characteristics of diode and estimate Boltzman constant.
  - To study characteristics of LED and estimate Planck's constant

#### **Unit III: Exploring magnetic properties of matter using Arduino**

- To verify Faraday's law and Lenz's law by measuring induced voltage across a coil subjected to varying magnetic field. Also, estimate dipole moment of the magnet.

#### **Unit IV: DC and AC Bridges** (at least one experiment)

- To compare capacitances using de Sauty Bridge
- To determine a Low Resistance by Carey - Foster Bridge

#### **Unit V: Network Theorems**

(at least one experiment)

- To verify the Thevenin and Norton theorems
- To verify the Superposition, and Maximum Power Transfer Theorems

#### **References (for Laboratory Work):**

- 1) Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
- 2) Engineering Practical Physics, S. Panigrahi and B. Mallick, 2015, Cengage Learning India Pvt. Ltd.
- 3) A Text Book of Practical Physics, I. Prakash and Ramakrishna, 11th Ed.2011, Kitab Mahal
- 4) Practical Physics, G. L. Squires, 2015, 4th Edition, Cambridge University Press

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**GENERIC ELECTIVE (GE - 12): THERMAL PHYSICS**

| Course Title & Code            | Credits | Credit distribution of the course |          |           | Eligibility criteria | Pre-requisite of the course | Department offering the course |
|--------------------------------|---------|-----------------------------------|----------|-----------|----------------------|-----------------------------|--------------------------------|
|                                |         | Lecture                           | Tutorial | Practical |                      |                             |                                |
| Thermal Physics<br><br>GE – 12 | 4       | 3                                 | 0        | 1         | Class XII pass       | NIL                         | Physics and Astrophysics       |

### LEARNING OBJECTIVES

This course will review the basic concepts of thermodynamics, kinetic theory of gases with a brief introduction to statistical mechanics. The primary goal is to understand the applications of fundamental laws of thermodynamics to various systems and processes. This coursework will also enable the students to understand the connection between the macroscopic observations of physical systems and microscopic behaviour of atoms and molecule through statistical mechanics.

### LEARNING OUTCOMES

At the end of this course, students will,

- Get an essence of the basic concepts of thermodynamics, the first and the second law of thermodynamics, the concept of entropy and the associated theorems, the thermodynamic potentials and their physical interpretations. They are also expected to learn Maxwell's thermodynamic relations.
- Know the fundamentals of the kinetic theory of gases, Maxwell-Boltzman distribution law, mean free path of molecular collisions, viscosity, thermal conductivity and diffusion.
- Learn about the black body radiations, Stefan- Boltzmann's law, Rayleigh-Jean's law and Planck's law and their significances.
- Learn the basics of quantum statistical distributions, viz., the Bose-Einstein statistics and the Fermi-Dirac statistics.

In the laboratory course, the students are expected to measure of Planck's constant using black body radiation, determine Stefan's constant, coefficient of thermal conductivity of a bad conductor and a good conductor, determine the temperature coefficient of resistance, study variation of thermo-emf across two junctions of a thermocouple with temperature etc.

## **SYLLABUS OF GE – 12**

### **THEORY COMPONENT**

#### **Unit 1: (12 Hours)**

Laws of Thermodynamics: Fundamental basics of Thermodynamic system and variables, Zeroth Law of Thermodynamics and temperature, First law and internal energy, various thermodynamical processes, Applications of First Law: general relation between  $C_p$  and  $C_v$ , work done during various processes, Compressibility and Expansion Coefficient, reversible and irreversible processes, Second law: Kelvin-Planck and Clausius statements, Carnot engine, Carnot cycle and theorem, basic concept of Entropy, Entropy changes in reversible and irreversible processes, Clausius inequality, Entropy-temperature diagrams.

#### **Unit 2: (08 Hours)**

Thermodynamical Potentials: Enthalpy, Gibbs, Helmholtz and Internal Energy functions, Maxwell's relations and applications - Clausius Clapeyron Equation, Expression for  $(C_p - C_v)$ ,  $C_p/C_v$ , TdS equations, energy equations for ideal gases.

#### **Unit 3: (8 Hours)**

Kinetic Theory of Gases: Derivation of Maxwell's law of distribution of velocities and its experimental verification, Mean free path (zeroth order only), Transport Phenomena: Viscosity, Conduction and Diffusion (for vertical case).

#### **Unit 4: (7 Hours)**

Theory of Radiation: Blackbody radiation, Spectral distribution, Derivation of Planck's law, Deduction of Wien's law, Rayleigh-Jeans Law, Stefan Boltzmann Law and Wien's displacement law from Planck's law.

#### **Unit 5: (10 Hours)**

Statistical Mechanics: Macrostate and Microstate, phase space, Entropy and Thermodynamic Probability, Maxwell-Boltzmann law, Fermi-Dirac distribution law - Bose-Einstein distribution law - comparison of three statistics.

#### **References:**

##### **Essential Readings:**

- 1) A Treatise on Heat, Meghnad Saha, and B. N. Srivastava, 1969, Indian Press.
- 2) Heat and Thermodynamics, M. W. Zemasky and R. Dittman, 1981, McGraw Hill.
- 3) Thermodynamics, Kinetic theory and statistical thermodynamics, F. W. Sears and G. L. Salinger. 1988, Narosa.
- 4) Thermal Physics, A. Kumar and S. P. Taneja, 2014, R. Chand Publications.
- 5) Thermal Physics: S. C. Garg, R. M. Bansal and C.K. Ghosh, 2nd Ed. Tata McGraw-Hill.

##### **Additional Readings:**

- 1) Concepts in Thermal Physics: Blundell and Blundell, 2nd Ed. 2009, Oxford Univ. Press.

- 2) An Introduction to Thermal Physics: D. Schroeder 2021, Oxford Univ. Press (earlier published by Pearsons).
- 3) Heat, Thermodynamics and Statistical Physics, Brij Lal, N. Subrahmanyam and P. S. Hemne, S. Chand and Company.

### **PRACTICAL COMPONENT- 30 Hours**

- Sessions on the construction and use of specific measurement instruments and experimental apparatuses used in the thermal physics lab, including necessary precautions.
- Sessions on the review of experimental data analysis, sources of error and their estimation in detail, writing of scientific laboratory reports including proper reporting of errors.
- Application to the specific experiments done in the lab.

Every student must perform at least four experiments from the following list.

- 1) To determine Mechanical Equivalent of Heat, J, by Callender and Barne's constant flow method.
- 2) Measurement of Planck's constant using black body radiation.
- 3) To determine Stefan's Constant.
- 4) To determine the coefficient of thermal conductivity of Cu by Searle's Apparatus.
- 5) To determine the coefficient of thermal conductivity of a bad conductor by Lee and Charlton's disc method by steam or electrical heating.
- 6) To determine the temperature co-efficient of resistance by Platinum resistance thermometer.
- 7) To study the variation of thermos-emf across two junctions of a thermocouple with temperature.

### **References (For Laboratory Work):**

- 1) Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
- 2) A Text Book of Practical Physics, Indu Prakash and Ramakrishna, 11th Edition, 2011, Kitab Mahal.
- 3) A Laboratory Manual of Physics for Undergraduate Classes, D. P. Khandelwal, 1985, Vani Publication.
- 4) Practical Physics, G. L. Squires, 2015, 4th Edition, Cambridge University Press.
- 5) An Advanced Course in Practical Physics: D. Chattopadhyay and P. C. Rakshit, New Central Book Agency

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**GENERIC ELECTIVE (GE - 13): MODERN PHYSICS**

| Course Title & Code           | Credits | Credit distribution<br>of the course |          |           | Eligibility<br>criteria | Pre-requisite<br>of the course |
|-------------------------------|---------|--------------------------------------|----------|-----------|-------------------------|--------------------------------|
|                               |         | Lecture                              | Tutorial | Practical |                         |                                |
| Modern Physics<br><br>GE – 13 | 4       | 3                                    | 0        | 1         | Class XII pass          | NIL                            |

### LEARNING OBJECTIVES

The objective of this course is to teach the physics foundation necessary for learning various topics in modern physics which are crucial for understanding atoms, molecules, photons, nuclei and elementary particles. These concepts are also important to understand phenomena in Laser physics, condensed matter physics and astrophysics.

### LEARNING OUTCOMES

After getting exposure to this course, the following topics would have learnt,

- Main aspects of the inadequacies of classical mechanics as well as understanding of the historical development of quantum mechanics, laying the foundation of modern physics.
- Formulation of Schrodinger equation and the idea of probability interpretation associated with wave-functions.
- The spontaneous and stimulated emission of radiation, optical pumping and population inversion, Basic lasing action.
- The properties of nuclei like density, size, binding energy, nuclear force and structure of atomic nucleus, liquid drop model and mass formula.
- Radioactive decays like alpha, beta, gamma decay. Neutrino, its properties and its role in theory of beta decay.
- Fission and fusion: Nuclear processes to produce nuclear energy in nuclear reactor and stellar energy in stars.

In the laboratory course, the students will get opportunity to measure Planck's constant, verify photoelectric effect, and determine  $e/m$  of electron and work function of a metal. They will also find wavelength of Laser sources by single and double slit experiment, wavelength and angular spread of He-Ne Laser using plane diffraction grating.

## **SYLLABUS OF GE – 13**

### **THEORY COMPONENT**

#### **Unit 1: (10 Hours)**

Origin of Modern Physics: Blackbody Radiation: Failure of explanation from classical theory; Planck's idea of a quantum; Quantum theory of Light: Photo-electric effect and Compton scattering, de Broglie wavelength and matter waves; Davisson-Germer experiment; Wave description of particles by wave packets, Group and Phase velocities and relation between them.

#### **Unit 2: (10 Hours)**

Problems with Rutherford model: Instability of atoms and observation of discrete atomic spectra; Bohr's quantization rule and atomic stability; calculation of energy levels for hydrogen-like atoms and their spectra.

Uncertainty principle: Gamma ray microscope thought experiment; Wave-particle duality leading to Heisenberg uncertainty principle; Impossibility of an electron being in the nucleus, Energy-time uncertainty principle; origin of natural width of emission lines

#### **Unit 3: (10 Hours)**

Basics of quantum Mechanics: Two-slit interference experiment with photons and electrons; Concept of wave functions, linearity and superposition, Time independent Schrodinger wave equation for non-relativistic particles; Momentum and Energy operators; physical interpretation of a wave function, probabilities, normalization and probability current densities in one dimension. Problem: One dimensional infinitely rigid box. An application: Quantum dot.

#### **Unit 4: (05 Hours)**

X-rays: Ionizing Power, X-ray Diffraction, Bragg's Law. Critical Potentials, X-rays-Spectra: Continuous and Characteristic X-rays, Moseley's Law.

LASERs: Properties and applications of Lasers. Emission (spontaneous and stimulated emissions) and absorption processes, Metastable states, components of a laser and lasing action.

#### **Unit 5: (10 Hours)**

Nuclear Physics: Size and structure of atomic nucleus and its relation with atomic weight; Nature of nuclear force, Stability of the nucleus; N-Z graph, Drip line nuclei, Binding Energy, Liquid Drop model: semi-empirical mass formula.

Radioactivity: Different equilibrium, Alpha decay; Beta decay: energy released, spectrum and Pauli's prediction of neutrino; Gamma ray emission, energy-momentum conservation:

Fission and fusion: Mass deficit and generation of energy; Fission: nature of fragments and emission of neutrons. Fusion and thermonuclear reactions driving stellar evolution (brief qualitative discussions only).



**References:****Essential Readings:**

- 1) Concepts of Modern Physics, Arthur Beiser, 2002, McGraw-Hill.
- 2) Modern Physics by R. A. Serway, C. J. Moses and C. A. Moyer, 3<sup>rd</sup> edition, Thomson Brooks Cole, 2012.
- 3) Modern Physics for Scientists and Engineers by S. T. Thornton and A Rex, 4<sup>th</sup> edition, Cengage Learning, 2013.
- 4) Concepts of Nuclear Physics by B. L. Cohen, Tata McGraw Hill Publication, 1974.
- 5) Quantum Mechanics: Theory and Applications, Ajoy Ghatak and S. Lokanathan, Laxmi Publications, 2019

**Additional Readings:**

- 1) Six Ideas that Shaped Physics: Particle Behave like Waves, T.A. Moore, 2003, McGraw Hill.
- 2) Thirty years that shook physics: the story of quantum theory, George Gamow, Garden City, NY: Doubleday, 1966.
- 3) New Physics, ed. Paul Davies, Cambridge University Press (1989).
- 4) Quantum Theory, David Bohm, Dover Publications, 1979.
- 5) Lectures on Quantum Mechanics: Fundamentals and Applications, eds. A. Pathak and Ajoy Ghatak, Viva Books Pvt. Ltd., 2019
- 6) Quantum Mechanics, Robert Eisberg and Robert Resnick, 2<sup>nd</sup> Edn., 2002, Wiley.
- 7) Basic ideas and concepts in Nuclear Physics: An introductory approach by K Heyde, third edition, IOP Publication, 1999.

**PRACTICAL COMPONENT – 30 Hours**

- Sessions on the construction and use of specific measurement instruments and experimental apparatuses used in the modern physics lab, including necessary precautions.
- Sessions on the review of experimental data analysis, sources of error and their estimation in detail, writing of scientific laboratory reports including proper reporting of errors.
- Application to the specific experiments done in the lab.

Every student must perform at least 06 experiments from the following list of experiments.

- 1) Measurement of Planck's constant using black body radiation and photo-detector.
- 2) Photo-electric effect: estimate Planck's constant using graph of maximum energy of photo-electrons versus frequency of light.
- 3) To determine work function of material of filament of directly heated vacuum diode.
- 4) To determine the Planck's constant using LEDs, using at least 4 LEDs.
- 5) To determine the wavelength of H-alpha emission line of Hydrogen atom.
- 6) To determine the value of  $e/m$  by (a) Magnetic focusing or (b) Bar magnet.
- 7) To setup the Millikan oil drop apparatus and determine the charge of an electron.
- 8) To show the tunneling effect in tunnel diode using I-V characteristics.
- 9) To determine the wavelength of laser source using diffraction of single slit.

- 10) To determine wavelength and angular spread of He-Ne laser using plane diffraction grating.
- 11) To determine the wavelength of laser source using diffraction of double slits.

**References (for Laboratory Work):**

- 1) Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
- 2) Advanced Level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4<sup>th</sup> Edition, reprinted 1985, Heinemann Educational Publishers.
- 3) A Text Book of Practical Physics, Indu Prakash and Ramakrishna, 11<sup>th</sup> Edition, 2011, Kitab Mahal, New Delhi.
- 4) Practical Physics, G. L. Squires, 2015, 4<sup>th</sup> Edition, Cambridge University Press.
- 5) B. Sc. Practical Physics, Geeta Sanon, R. Chand, 2016.

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**GENERIC ELECTIVE (GE - 14): INTRODUCTORY ASTRONOMY**

| Course Title & Code                   | Credits | Credit distribution<br>of the course |          |           | Eligibility<br>criteria | Pre-requisite<br>of the course |
|---------------------------------------|---------|--------------------------------------|----------|-----------|-------------------------|--------------------------------|
|                                       |         | Lecture                              | Tutorial | Practical |                         |                                |
| Introductory Astronomy<br><br>GE – 14 | 4       | 3                                    | 1        | 0         | Class XII pass          | NIL                            |

**LEARNING OBJECTIVES**

This course is meant to introduce undergraduate students to the wonders of the Universe. Students will understand how astronomers over millennia have come to understand mysteries of the universe using laws of geometry and physics, and more recently chemistry and biology. They will be introduced to the Indian contribution to astronomy starting from ancient times up to the modern era. They will learn about diverse set of astronomical phenomenon, from the daily and yearly motion of stars and planets in the night sky which they can observe themselves, to the expansion of the universe deduced from the latest observations and cosmological models. Students will also be introduced to internet astronomy and the citizen science research platform in astronomy. The course presupposes school level understanding of mathematics and physics.

**LEARNING OUTCOMES**

After completing this course, student will gain an understanding of,

- Different types of telescopes, diurnal and yearly motion of astronomical objects, astronomical coordinate systems and their transformations
- Brightness scale for stars, types of stars, their structure and evolution on HR diagram
- Components of solar system and its evolution
- Current research in detection of exoplanets
- Basic structure of different galaxies and rotation of the Milky Way galaxy
- Distribution of chemical compounds in the interstellar medium and astrophysical conditions necessary for the emergence and existence of life
- Internet based astronomy and the collaborative citizen astronomy projects
- India's contribution to astronomy, both in ancient times and in modern era.

## **SYLLABUS OF GE – 14 (Lecture-45 hours)**

### **THEORY COMPONENT**

#### **Unit 1:**

Introduction to Astronomy and Astronomical Scales: History of astronomy, wonders of the Universe, overview of the night sky, diurnal and yearly motions of the Sun, size, mass, density and temperature of astronomical objects, basic concepts of positional astronomy: Celestial sphere, Astronomical coordinate systems, Horizon system and Equatorial system

#### **Unit 2:**

Basic Parameters of Stars: Stellar energy sources, determination of distance by parallax method, aberration, proper motion, brightness, radiant flux and luminosity, apparent and absolute magnitude scales, distance modulus, determination of stellar temperature and radius, basic results of Saha ionization formula and its applications for stellar astrophysics, stellar spectra, dependence of spectral types on temperature, luminosity classification, stellar evolutionary track on Hertzsprung-Russell diagram

#### **Unit 3:**

Astronomical Instruments: Observing through the atmosphere (Scintillation, Seeing, Atmospheric Windows and Extinction). Basic Optical Definitions for Telescopes: Magnification, Light Gathering Power, Limiting magnitude, Resolving Power, Diffraction Limit. Optical telescopes, radio telescopes, Hubble space telescope, James Web space telescope, Fermi Gamma ray space telescope.

Astronomy in the Internet Age: Overview of Aladin Sky Atlas, Astrometrica, Sloan Digital Sky Survey, Stellarium, virtual telescope

Citizen Science Initiatives: Galaxy Zoo, SETI@Home, RAD@Home India

#### **Unit 4:**

Sun and the solar system: Solar parameters, Sun's internal structure, solar photosphere, solar atmosphere, chromosphere, corona, solar activity, origin of the solar system, the nebular model, tidal forces and planetary rings

Exoplanets: Detection methods

#### **Unit 5:**

Physics of Galaxies: Basic structure and properties of different types of Galaxies, Nature of rotation of the Milky Way (Differential rotation of the Galaxy), Idea of dark matter

Cosmology and Astrobiology: Standard Candles (Cepheids and SNe Type Ia), Cosmic distance ladder, Olber's paradox, Hubble's expansion, History of the Universe, Chemistry of life, Origin of life, Chances of life in the solar system

#### **Unit 6:**



Astronomy in India: Astronomy in ancient, medieval and early telescopic era of India, current Indian observatories (Hanle-Indian Astronomical Observatory, Devasthal Observatory, Vainu Bappu Observatory, Mount Abu Infrared Observatory, Gauribidanur Radio Observatory, Giant Metre-wave Radio Telescope, Udaipur Solar Observatory, LIGO-India) (qualitative discussion), Indian astronomy missions (Astrosat, Aditya)

### **References:**

#### **Essential Readings:**

- 1) Seven Wonders of the Cosmos, Jayant V Narlikar, Cambridge University Press
- 2) Fundamental of Astronomy, H. Karttunen et al. Springer
- 3) Modern Astrophysics, B. W. Carroll and D. A. Ostlie, Addison-Wesley Publishing Co.
- 4) Introductory Astronomy and Astrophysics, M. Zeilik and S. A. Gregory, Saunders College Publishing.
- 5) The Molecular Universe, A. G. G. M. Tielens (Sections I, II and III), Reviews of Modern Physics, Volume 85, July-September, 2013
- 6) Astronomy in India: A Historical Perspective, Thanu Padmanabhan, Springer

#### **Useful websites for astronomy education and citizen science research platform**

- 1) <https://aladin.u-strasbg.fr/>
- 2) <http://www.astrometrica.at/>
- 3) <https://www.sdss.org/>
- 4) <http://stellarium.org/>
- 5) <https://www.zooniverse.org/projects/zookeeper/galaxy-zoo/>
- 6) <https://setiathome.berkeley.edu/>
- 7) <https://www.radathomeindia.org/>

#### **Additional Readings:**

- 1) Explorations: Introduction to Astronomy, Thomas Arny and Stephen Schneider, McGraw

Hill

- 2) Astrophysics Stars and Galaxies K. D. Abhyankar, Universities Press
- 3) Textbook of Astronomy and Astrophysics with elements of cosmology, V. B. Bhatia, Narosa Publication.
- 4) Baidyanath Basu, An introduction to Astrophysics, Prentice Hall of India Private Limited.
- 5) The Physical Universe: An Introduction to Astronomy, F. H. Shu, University Science Books

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